Chapter

Mexican Indigenous Species with Agroecological Uses

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Abstract

Mexico is considered one of the twelve megadiverse countries, and they together harbor 60–70% of the biodiversity from the planet. Mexico with Brazil, Colombia, and Indonesia occupied the principal positions. In Mexico, there are almost 50,000 plant species recognized now. Several of these plants are used since the pre-Hispanic age in religious ceremonies and medicinal treatments, but their potential in agroecology has not been exploited. There is not much information related to these alternative crops and their possible uses in agriculture. In this chapter, we will describe the main characteristics of the plant and its possible uses in agroecology.

Keywords: ancient plants, biocides, conservation, *Heliopsis*, *Tagetes*

1. Introduction

Biodiversity determines the interaction between organisms, their environment, and the evolution through the time [1]. It has been estimated that the number of species in the world is between 5 and 30 million [2], although it is difficult to establish these numbers with precision.

Because its large territory and microclimates, Mexico harbors a high number of plant species and genera, becoming one of the countries with the highest diversity in plants, reptiles, and mammals [3]. Mexico is one of the megadiverse countries and is estimated to harbor 10% of the planet flora [3]. It was calculated that Mexico has approximately 24,000 plant species, 535 mammal species, 804 reptile species, 361 amphibians, and 1107 birds, in accordance with Mexico's information at the Biological Diversity Agreement.

Several species are Mexicans exclusively; 50 to 60% of the known plant species are in the Mexican territory: 21 pine species, 146 agaves, and 175 cacti. In this chapter, we present some indigenous Mexican plant species and their agroecological uses that could represent interest for people.

2. Methodology

Several sources were consulted in order to obtain the information for this document that included databases, bibliographical sources, interviews with specialists and countrymen, and available information in the official catalogs of the plants.

3. Results

3.1 *Tagetes* genera

3.1.1 Botanical description

Asteraceae family is distributed mainly at the American continent, and 10% of the plant species is located in Mexico [4, 5]. The genus *Tagetes* is represented by 58 endemic species from America, and in Mexico there are 36 species. Three of them are introduced from Central and South America: *T. microglossa*, *T. minuta*, and *T. terniflora*. **Table 1** shows the taxonomical description for the genus *Tagetes*.

The *Tagetes* plants have pinnate leaves and stems with a growth from 1 cm to 2 m high, depending on the species. Their flowers are ligulated with sizes from 1 to 2 cm and growth around the plant in a radial form with a diameter of 4 to 6 cm. Flowers show red, orange, yellow, and white colors [6]. **Table 2** shows some of the characteristics of the plants from the genus *Tagetes* [6, 7].

3.1.2 Uses of the genus Tagetes

The *Tagetes* secondary metabolites give the plant the medicinal properties and the biological effects against several microorganisms (bacteria, protozoa, and fungi), insects, and nematodes that provoke some damage to plants; some of them are dangerous to animals and humans. Some species, such as *T. erecta*, *T. patula*, and *T. lucida*, produce pigments used in the agroindustry for the coloring of food products and as nutraceuticals for its antioxidant properties. **Table 3** included some of the species of the genus *Tagetes* cultivated in Mexico.

Kingdom	*Plantae*
Subkingdom	*Viridiplantae*
Infrakingdom	*Streptophyta*
Division	*Tracheophyta*
Subdivision	*Spermatophytina*
Infradivision	*Angiospermae*
Class	*Magnoliopsida*
Superorder	*Asteranae*
Order	*Asterales*
Family	*Asteraceae*
Tribe	*Tageteae*
Genus	*Tagetes*

Table 1.
Taxonomical classification for the genus Tagetes from the Integrated System of Information (SIIT, 2012).

Specie	Stem high (cm)	Petal num ber	Flower color	Flower sizes (mm)	Head flower color	Germination
T. lunulata	30-80	20-35	yellow	7-10	green	annual/herbal
T.foetidissima	20-80	4-8	yellow green	5-6.5	green	annual/herbal
T. multiflora	20	7-14	yellow	2-4	purple	annual/herbal
T.coronopifolia	50	5-20	yellow	2-4	purple	annual/herbal
T. linifolia	20-40	40-60	yellow, orange, red	5-12	green	perennial/herbal
T. lemmonii	30-100	30-60	yellow	10-15	green	perennial/herbal
T. stenophylia	50-100	3-60	yellow	8-12	radial	perennial/herbal
T. patula	20-85	56-70	yellow, orange, red	8-13	green	annual/herbal
T. persicaefolia	100	7-8	yellow	8-12	green	annual/herbal
T. erecta	40-60	40-90	yellow, orange	10-15	green	annual/herbal
T. moorei	8-40	10-20	yellow	8-10	green	annual/herbal
T. parryi	30-50	50-60	yellow	12-20	green	annual/herbal
T. minuta	150	3-5	yellow	0.5-1	green	annual/herbal
T. terniflora	160	3-5	yellow	0.5-1	red	annual/herbal
T. lúcida	100	5-8	yellow	6-7	green	perennial/herbal
T. arenícola	30-60	5-6	Yellow, orange	6-7	green	annual/herbal
T. linifolia	10-40	3-9	yellow	3-3.5	green	annual/herbal
T. micrantha	10-50	4-10	yellow	3-3.5	green	annual/herbal
T. subulata	10-50	10-20	Yellow, yellow	7-10	brown	annual/herbal

Table 2.
Morphological characteristics of some species of Tagetes *[6, 7].*

T. arenicola	*T. jaliscensis*	*T. moorei*	*T. pringlei*
T. coronopifolia	*T. lacera*	*T. mulleri*	*T. remotiflora*
T. epapposa	*T. lemmonii*	*T. nelsonii*	*T. stenophylla*
T. elongata	*T. linifolia*	*T. oaxacana*	*T. subulata*
T. erecta	*T. lunulata*	*T. palmerii*	*T. subvillosa*
T. filifolia	*T. lucida*	*T. parryi*	*T. tenuifolia*
T. foetidissima	*T. micrantha*	*T. patula*	*T. terniflora*
T. hartwegii	*T. minuta*	*T. persicaefolius*	*T. trirradiata*

Table 3.
Species del genus Tagetes *cultivated in Mexico [6].*

There are several reports related to the biocide effect of some species of *Tagetes* over plant parasites that affect the yield in potato and tomato [8–13]. The reported species are *T. patula, T.* minuta, and *T. erecta* that reduce the presence of parasites such as *Rh. Sanguineus*, *Phlebotomus duboscqi*, *Pratylenchus penetrans*, and *Meloidogyne incognita* [14].

The biological and chemical knowledge of *Tagetes* is not exhaustive, although in some species, such as *T. erecta* and *T. minuta*, the research had been extensive worldwide, because the commercial exploiting of the pigments and the essential oils results in the development of a very promising agroindustry in Africa, China, India, the USA, and Peru.

The main characteristic of *Tagetes* is that their species are aromatic that is related to the medicinal approach since the Mexican pre-Hispanic age. This knowledge had been conserved to the actual times in the traditional medicine.

3.1.3 Historical context and importance of the genus Tagetes

The plants of the genus *Tagetes* had been used since the pre-Hispanic age by the nuatlaca people. Its uses were described at the *Florentino Codex* by Fray Bernardino de Sahagún in the sixteenth century. An example is *T. lucida*, known in Nahuatl as yauhtli. It had been used as air freshener and ornamental in fire and rain celebrations and also was used as medicine for the treatment of fever and ulcers. Another example is *T. tenuilora*, used as an herbal food condiment.

The indigenous people also used *T. erecta* known as flor de Cempoalxóchitl used at the temples and houses in the sun and dead people (Dia de Muertos) festivities [6]. Now, flor de Cempoalxóchitl is still used in the traditional medicine as antiparasite and in the treatment of stomach, bazo, and liver diseases. Because of the high content of carotenoids, especially lutein, the flowers of *T. erecta* are used at the food industry as additive in the animal food for aves de corral, fishes, and crustaceans for the pigmentation of their skin, making them very attractive for their consumption [14].

The carotenoids of Cempoalxóchitl and other species of *Tagetes* are used in the treatment of human diseases. The xanthophylls and β-carotene (vitamin A precursor) have an antioxidant activity to protect from the damage provoked by the free radicals, responsible of several degenerative diseases, such as arteriosclerosis, arthritis, and carcinogenesis.

Because the use of pesticides in the crops culture, there are some problems in those and their products: high cost, plague resistance, and pollution. Now some strategies to avoid these problems are being looked for. *Tagetes* such as *T. minuta*,*T. patula*, and *T. erecta* produce terpenes and thiophenes with pesticidal and acaricidal capacity that could be used as extracts or in co-cultivation for the control of plagues that produce some damage in several cultures [8–13].

3.1.4 Tagetes production in Mexico

In Mexico there are 859 ha cultivated with *T. erecta*, 69.2% are grown in Puebla state, 10% in State of Mexico, 2.3% Michoacán state, and 0.33% in Mexico City. The rest of the production is in the states of Oaxaca, Guerrero, Hidalgo, Morelos, San Luis Potosí, Tlaxcala, and Durango. The year production reaches 6598 tons of flower with a value of 16 million Mexican pesos. The production is mainly for ornamental in the "Dia de Muertos" celebration [7]. *T. patula* is also used as ornamental; however, there is not available data for its production. The rest of the species are growing in a wild way [6].

The production system is through transplant. The plantlets are developed in seedlings, and they are transplanted to the field when they are 10 cm high (20 to 45 days). In the field, the plantlets continue their development until flowering until the end of the cycle (110 days). The flower yields are variable in the culture; they are from 12 to 30 tons of flower/ha, in a maximal of seven cuts [6].

3.1.5 Taxonomical classification and geographical distribution of the Tagetes

The genus *Tagetes* is distributed from the southwest of the USA to the south of Argentina. In Mexico, 32 from the 56 discovered species had been found, and they are localized in several states around the country. Several authors classified the *Tagetes* species based on its morphological characteristics; however, these species show very similar characteristics, causing confusion and erroneous taxonomical classifications in several species. There are different names for the same species, or also some plants considered with independent species are now recognized as members of the same species, i.e.,*T. tenuifolia* and *T. peduncularis*, which have been renamed as *T. lunulata* [6]. There is also the case of *Addenopapus persicaefolius*, incorporated to the genus *Tagetes* by molecular evidence [6].

Since 2003, in Mexico, a project was initiated for the compilation and analysis of the available information of the species of the genus *Tagetes*; its center of origin and diversity is Mexico. **Table 3** shows a list of 32 species found in Mexico [6].

3.2 Cactaceae family

3.2.1 Geographical distribution

The most notable plants in the Mexican arid landscapes, including the *Agave*, mesquites, and *Yucca*, are the Cactaceae family [15, 16]. The Cactaceae family is native from America. It is found from the south of Canada to Argentina; Mexico is harboring the highest diversity of species and a high index of endemism (78%) [17].

The distribution in Mexico includes several environments, such as Zapotitlán de las Salinas in Tehuacan, at Puebla; the Tomellin Canyon, the Sierra Mixteca in Oaxaca; the ravines in Metztitlan, Hidalgo; the Rio Balsas Basin; the Infiernillo ravines in Querétaro; the Potosino-Zacatecano plateau; and the Baja California Peninsula [15].

The Cactaceae plants are distributed all around the country, and they are mainly concentrated at the arid and semiarid lands of San Luis Potosí, Zacatecas, Aguascalientes, Querétaro, Hidalgo, and Chihuahua [17]. The Querétaro and San Luis Potosí are the center of distribution of a high number of species, because their geographical and climate isolation from the rest of the country have originated several members of this plant family. The phytogeographical and biological importance of this area is due to the species that grow, not present in any other regions of the planet [18].

3.2.2 Botanical description

The Cactaceae are perennial plants, succulents, terrestrial, geophytes, thorny, arborescent, or epiphytes. Their epidermis is glabra or pubescent; they develop fibers and tuberculous roots. The stems are globose, cylindrical, columnar, or flattened, with tubers or moms (mamilas) in a spiral disposition, with a constant number in each species; there are some other structures such as wings, ribs, or flatted and green phylloclades. The leaves are laminar in the primitive genera and absent in other genera. The areoles harboring reproductive and vegetative meristems, such as axillar buds with spines and glands, can produce flowers or leaves [18].

The flowers are zoophilous, mainly sessile, isolated, and rarely grouped as inflorescence, such as panicles or cimosas (*Pereskia*) or terminal (*Pterocactus*); they are hermaphrodites, sometimes unisexual, and almost actinomorphic with betalains. The pericarpel, tissue from the stem located around the ovary or the receptacle, is glabro or covered with areoles in a spiral way. They are normally covered by scales, and they used to be integrated with the perianth, showing glochids and spines. The perianth is formed by external or internal segments of petaloids, associated in series in spiral form. The superior ovary is found in a unique species *Pereskia aculeata,* although in general the ovary is inferior or semi-inferior, with 3 to 20 unilocular carpels. The flowers have a unique style, and the stigmas develop several lobules with different numbers depending on the species. The ovules are characterized by their long funicles, concrescent in fascicles [6].

The fruit could be flesh, dried or semidried, indehiscent or dehiscent, and sometimes glabro or with areoles harboring spines. The succulence is due to the funicles that accumulate sugar during fruit ripening.

The seeds differentiate in a perisperm as a food storage system for the embryo; the testa could be thin or thick with or without a ring (strophiole) originated at the funicle. The cotyledons are foliaceous at the primitive genera and reduced or primitive in mainly all the species [6].

3.2.3 Endangered species

In Mexico, the Cactaceae are endemic plants that play an important role in a biological, social, and economic point of view. However, the plantlets and the adult plants have been stolen from their habitat for commercial proposes in the USA, Japan, and several European countries [15, 16]. In the last years, there is an increase in the demand for the cactus plants, mainly in the species considered as rare or unique; these plants are commercialized by national or international collectors. These plants are collected in situ, increasing the pressure over the wild populations and affecting the rate of natural reproduction taken some species to the category of endangered species [15, 16]. Now 255 taxons of Cactaceae are considered endangered species as described by Norma Oficial Mexicana-059-ECOL-2001. *The Red Book* (IUCN) and the CITES appendix include 65 and 41 taxons, respectively, as endangered species [19].

3.2.4 Botanical uses of the Cactaceae family

Ortegocactus macdougallii (Alexander)

It is important as ornamental and appreciated by the collectors because of its flowers and stems; this plant helps in the soil restoration and erosion control and is a very good rain harvester.

Turbinicarpus ysabelae (Schlange) (John & Riha)

It is important as ornamental, its fruits are a good source for food to the local fauna, and this plant helps to control the soil structure and erosion and harvest polluted gases.

Turbinicarpus schmiedickeanus ssp. jauernigii (G. Frank) (D.R. Hunt)

It is important as ornamental and in the control of soil erosion; this plant is used as source of phytochemicals (alkaloids) for medicinal and ludic purposes.

Turbinicarpus swobodae (Diers & Esteves)

It is used as ornamental and helps in the control of soil erosion. This plant helps to harvest the water from the rain and in the entrapment of environmental pollutants.

Astrophytum asterias (Zucc.) (Lem)

These plants produce secondary metabolites (alkaloids) and are used in religious ceremonies and in the traditional medicine.

Mammillaria hernandezii (Glass *et* Foster)

It is used as ornamental use and helps in the control of soil erosion.

3.3 Chilcuague (*Heliopsis longipes*)

3.3.1 Origin and common uses

Heliopsis longipes, which common name is “chilcuague,” is a Mexican herbaceous plant which is found in a mountainous area where the states of.

San Luis Potosí, Guanajuato, and Querétaro meet. Pre-Hispanic Mexicans employed the extracts from the root system of this plant to heal diverse pains such as toothache, earache, and headache [20]; it was recognized for its pungent taste and for causing numbing and salivation. Three centuries later, in 1948, Elbert L. Little Jr. published a small description of *Heliopsis longipes* and suggests the potential use of the plant as an insecticidal [21].

Despite its importance the use of chilcuague roots was marginal and restricted to the communities of the localities where the plant grows; one of the main reasons for this phenomenon is the fact that the massive propagation of the plant has experienced problems, mainly in transplanting after seedling stage.

3.3.2 Agroecological potential

Alkamides are secondary metabolites comprising over 200 related compounds widely distributed in plants. They have been found in ten plant families: Aristolochiaceae, Asteraceae, Brassicaceae, Convolvulaceae, Euphorbiaceae, Menispermaceae, Piperaceae, Poaceae, Rutaceae, and Solanaceae. The Asteraceae, Piperaceae, and Rutaceae families comprise the diverse species that contain high levels of alkamides [22–24]. The general structure of alkamides originates from the condensation of an unsaturated fatty acid and an amine [25]. Although different chain length alkamides have been found in plants, most of them contain a 2*E* double bond conjugated to the amide group substituted with an *N*-isobutyl group. Recently, it has been shown that alkamides are the main compounds found in *Heliopsis longipes* roots and are responsible for diverse biological effects on bacteria, insects, plants, and humans [26, 27]. The main alkamides isolated from chilcuague roots are *N*-isobutyl-2*E*,6*Z*,8*E*-decatrienamide (afinin), *N*-isobutyl-2*E*-decenamide, and *N*-isobutyl-decanamide. The biological effects of affinine on diverse organisms have been tested:

The effect of ethanolic extract from *Heliopsis* roots and purified affinine was tested on grubs of *Aedes aegypti*, the vector for dengue transmission. Both, the extract and pure affinine, showed a high toxic effect on the insect grubs, demonstrating that the molecule responsible for this lethality is affinine. Despite the exciting role of affinine on *Aedes aegypti* mortality, further studies are most performed in order to know the specific target of affinine.

Affinine and affinine-derived molecules display a negative activity against mycelial growth of diverse phytopathogenic fungi, such as *Phytophthora infestans*, *Fusarium* spp., *Sclerotium rolfsii*, and *Verticillium* spp. Also negative effect on cell growth and division of *Escherichia coli* and *Bacillus subtilis* was shown.

Ramírez-Chávez and co-workers also investigated the effects of affinine and its derivates, *N*-isobutyl-2*E*-decenamide and *N*-isobutyl-decanamide, on plant growth and early root development of *Arabidopsis thaliana*. They found that treatments with affinine, in the range of 7×10^{-6}–2.8×10^{-5} M, enhanced the primary root growth and root hair elongation, whereas higher concentrations inhibited primary root growth that is related to a reduction in cell proliferating activity and cell elongation. Also, *N*-isobutyl-2*E*-decenamide and *N*-isobutyldecanamide were found to stimulate root hair elongation at concentrations between 10 and 8 and 10 and 7 M [27]. Similar results have been obtained using potato, tobacco, and rice, as experimental models. Taken together these results point to alkamides as a new group of plant growth-promoting substances and open the possibility of using them as molecules for improving plant production. Besides several new and more detailed analyses of the effects of affinine on the diverse experimental models, previously described studies point out "chilcuague" as one of the Mexican plants with huge agroecological potential.

4. Discussion

4.1 The importance of the indigenous plants

Several indigenous plants are in the country since at least 20,000 years ago, and several of them helped to the initial human settlement, as an important source of food for humans and animals and in some other uses, such as medical, ludic and ornamental, or spiritual. In several cases, they were considered in a sacred level and included in several rituals and ceremonies as documented in the antique codices. Some of them persist in the diet of the people from the country.

Now, these indigenous plants have been revaluated for the nutraceutical contribution in the diet, and they are included now in a possible treatment in some metabolic or degenerative diseases, making them very attractive to the pharmaceutical industry. Some of the indigenous plant uses are involved in the restoration and maintenance of the ecological systems, since the ancient times, and they are used in unique agroecological systems. Mexico is harboring one of the most extensive collections of plants around the world, and their uses are still not well understood.

Plant	Ecology	Ecological niche	Possible uses	Possibilities of cultivation	Cultivation techniques
Tagetes erecta	Subtropical	Pollination Control of microbial, insects, and nematodes	Fungicidal Bactericidal Nematicidal Food industry	Yes	Seed production
Tagetes spp.	Subtropical	Pollination Control of microbial, insects, and nematodes	Fungicidal Bactericidal Nematicidal Food industry Essential oils production	Yes	Seed production
Cactaceae family	Arid and semiarid	Erosion control and soil restauration	Ornamental Soil restoration Erosion control Food Industry Ludic	Yes	Seed production Stems Vegetative propagation Tissue culture
Heliopsis longipes	Tropical and subtropical	Unique, control of microbial, insects, and nematodes	Bactericidal Fungicidal Food industry Pharmacological Growth regulator	Yes	Seed production Vegetative propagation Tissue culture

Table 4.
Ecological characteristics of indigenous Mexican plants.

4.2 Modern uses for indigenous plants

In order to identify the importance of the plants, several scientific efforts are in the course trying to determine the biological activity of the plants. **Table 4** includes a compilation of characteristics of the plants described in the chapter. As seen several of the uses are focused on the agronomic characteristics as substitutes of the agrochemical compounds for the control of bacteria, fungi, insect, and nematodes making them very attractive for biological control in agriculture.

The biological functions are based on the secondary metabolite content; they make the plants very attractive for food industry, coloring, and tasting and even give structure to the new food products.

In this new era, the medicinal and ludic uses are ligated to avoid the mental sickness in the new societies. The ancient plants were used since the past with these proposals, with very good results, and now there is a promising use in the treatment of mental disease difficult to control in other way.

4.3 Endangered species

One of the problems in the endogenous species is the extraction of plantlets and adult plants from their habitat and being stolen for commercial purposes. It makes the plants go to a critical stage of surveillance. In several cases, the discovery of new uses has carried out an exhausted exploiting of plants without a program for reproduction and conservation of the plant species. Another situation is related to the genomic content in these species, complex polyploids with huge sizes of genome, and although they are important as ancient plants, no sequencing problems are under way.

5. Conclusions

Mexico is the center of origin for several plants, because of its privileged geographical position that includes the orography and the microclimates. The indigenous plants have been used since centuries by the inhabitants. There are several antique codices that describe the origin and uses of almost all the plants, that include ludic, ceremonial, ornamental, medicinal, and agroecological. Several Mexican plants are factories of secondary metabolites with biocide activity, such as microbial (bactericidal, fungicidal, and nematicidal) and insecticidal, with an important use in agriculture. Some other plants could help in the preservation of the soil structure, collecting water and keeping the soil in the optimal conditions for agriculture. Although everyday there is more information regarding the native plants, more knowledge is still needed in order to preserve these valuable plants.

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